

Venus Atmosphere Platform Options Reconsidered

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Author background

Flights over tropical rain forest canopy

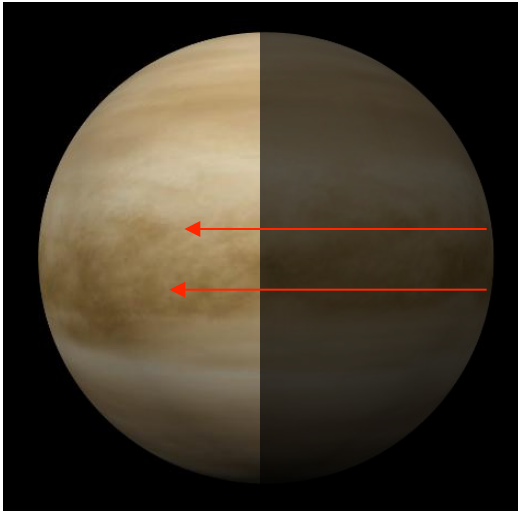


Content

- VEGA Super-Pressure Balloons (SPBs)
- VEGA derived vertical wind velocity
- EVE SPB (some concerns)
- Alternative platform options
 - Phase Change (Oscillating) Balloons
 - Other concepts

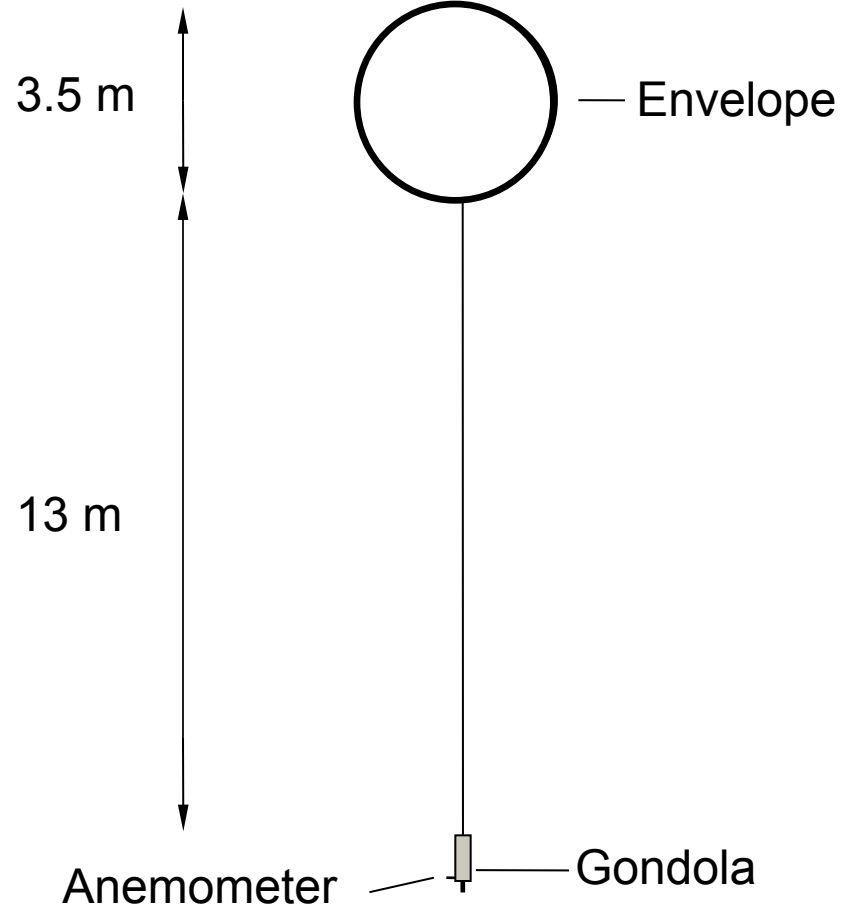
VEGA 1 and 2, June 1985

53.5 km altitude westward drift
46 hr limited by battery capacity

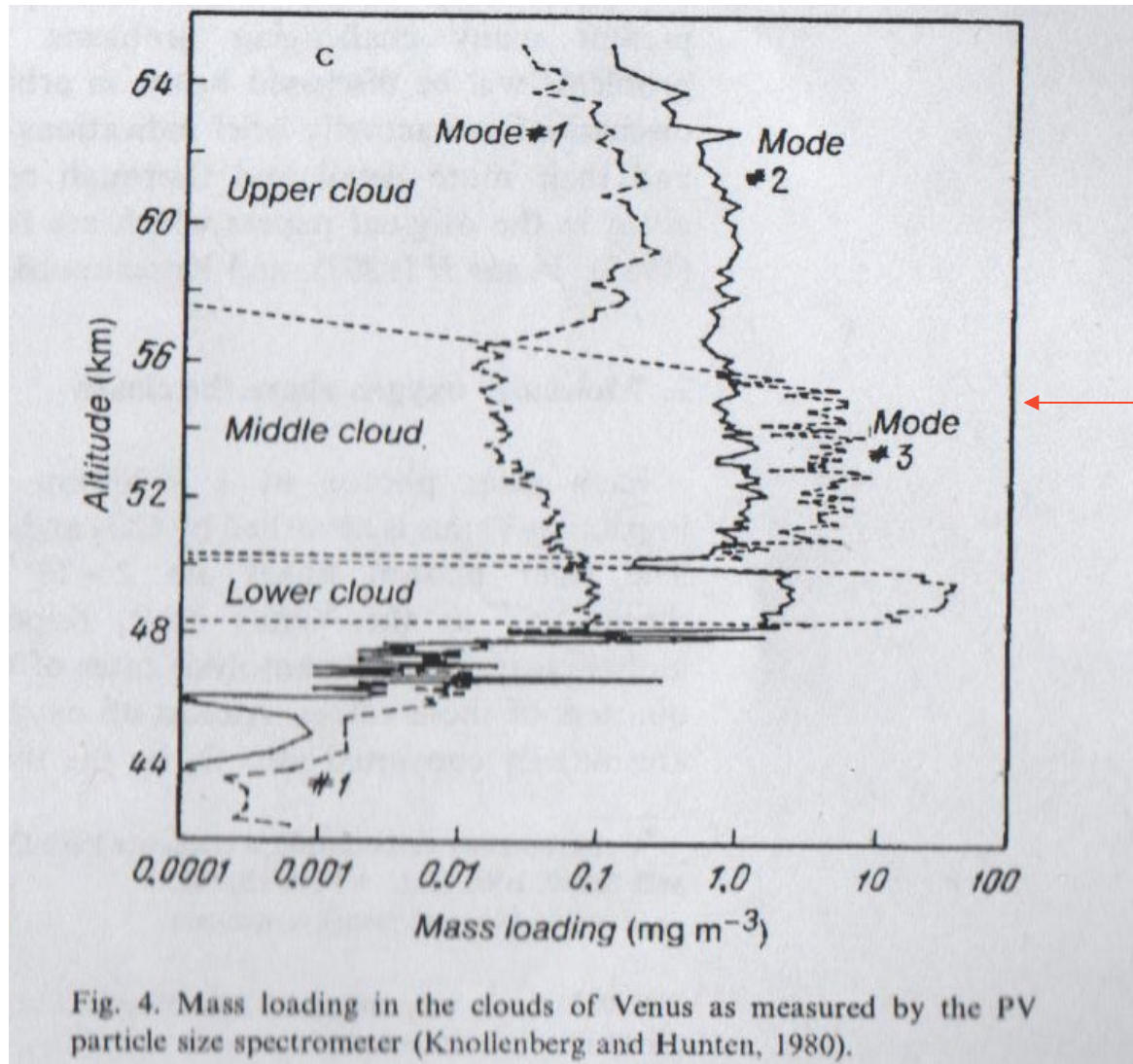


Blamont: “Demonstration or feasibility study” (1985)

Helium-filled spherical
Super-Pressure Balloon
(SPB)



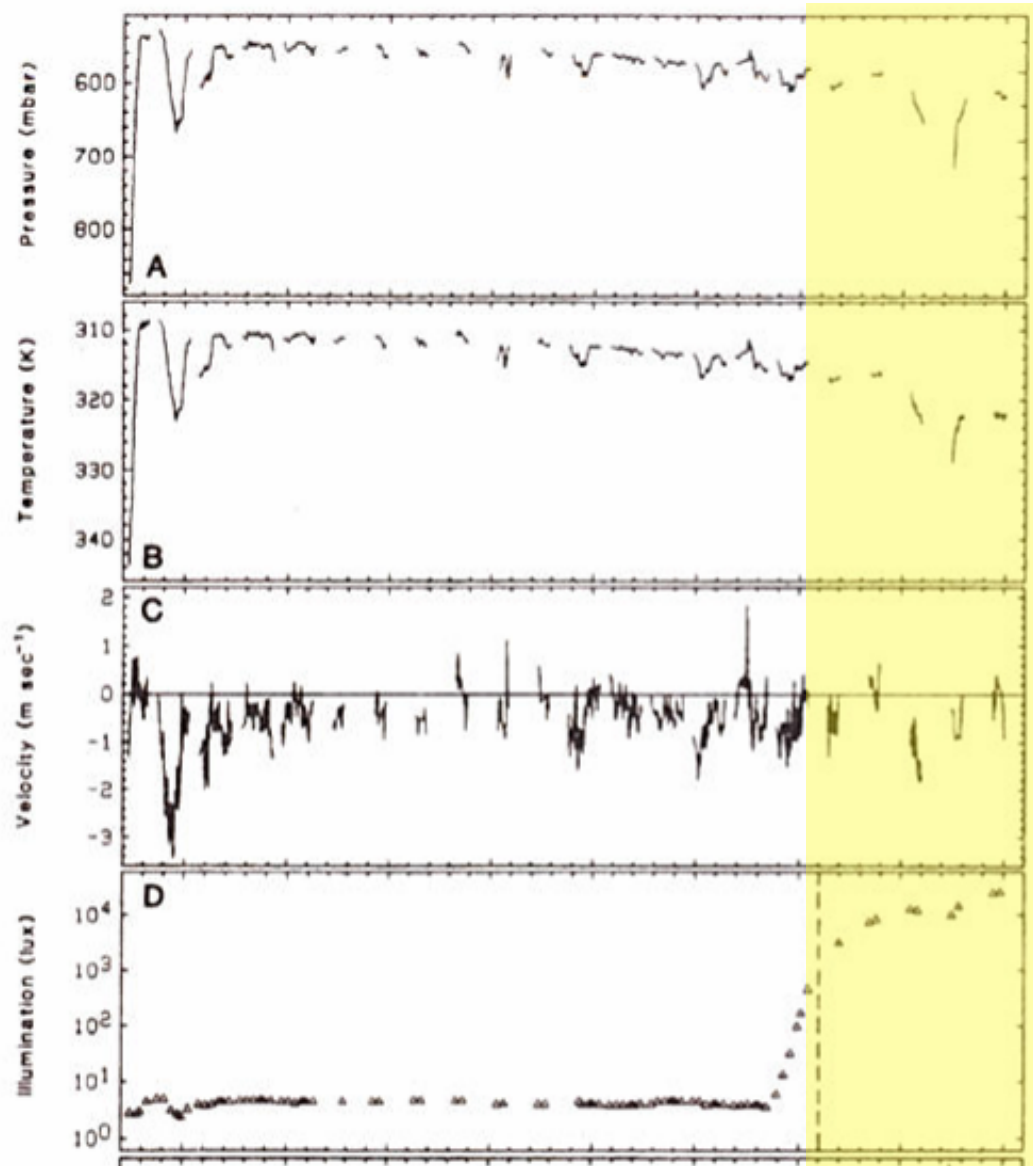
Cytherean Triple Cloud Layer



EVE &
Vega
SPBs

VEGA 1

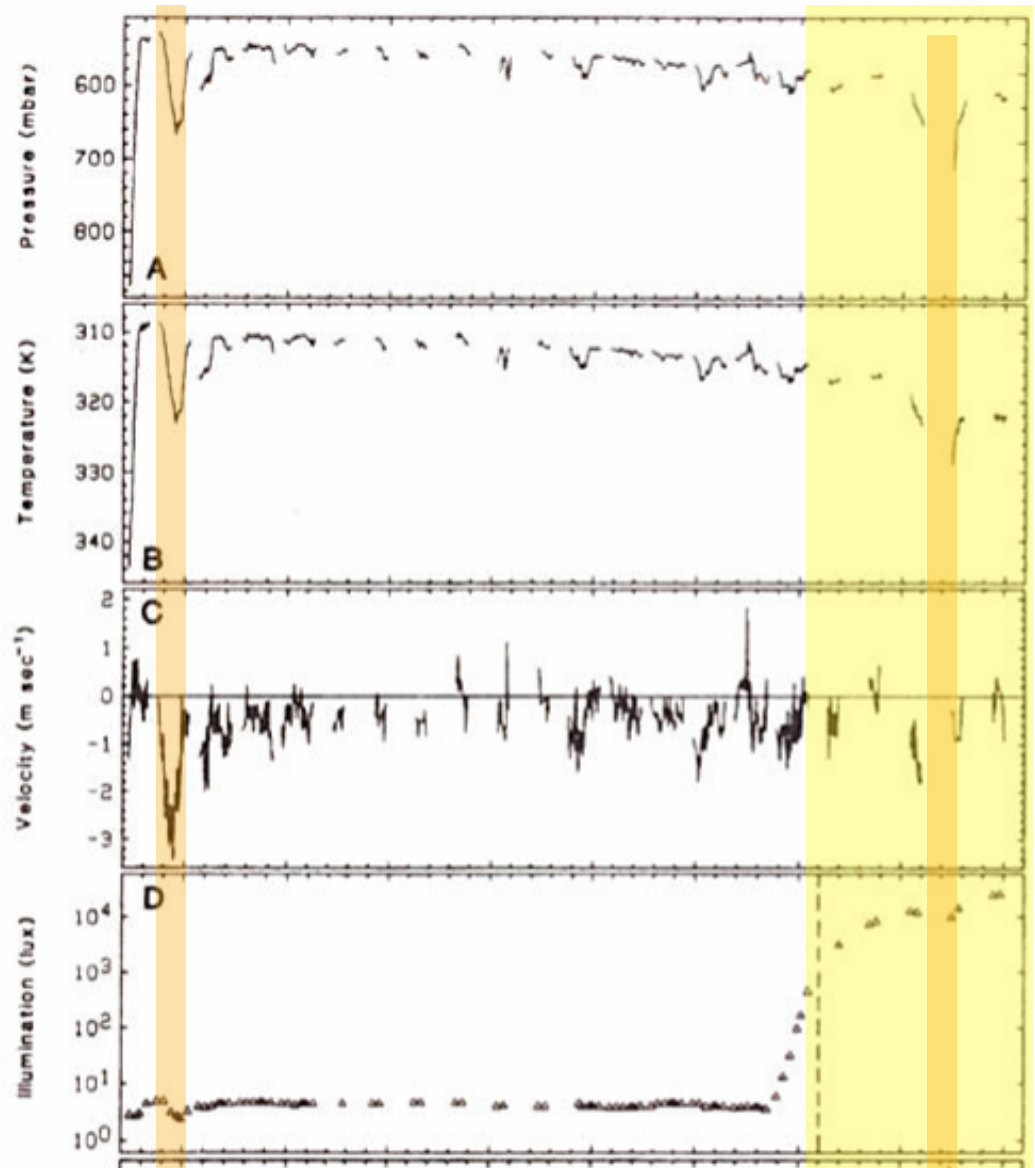
- Pressure (mBar) ↓
- Temperature (K) ↓
- Derived vertical wind velocity (m/s)
- Illumination (lux) ↑



Sagdeev et al. Science (1985)

VEGA 1

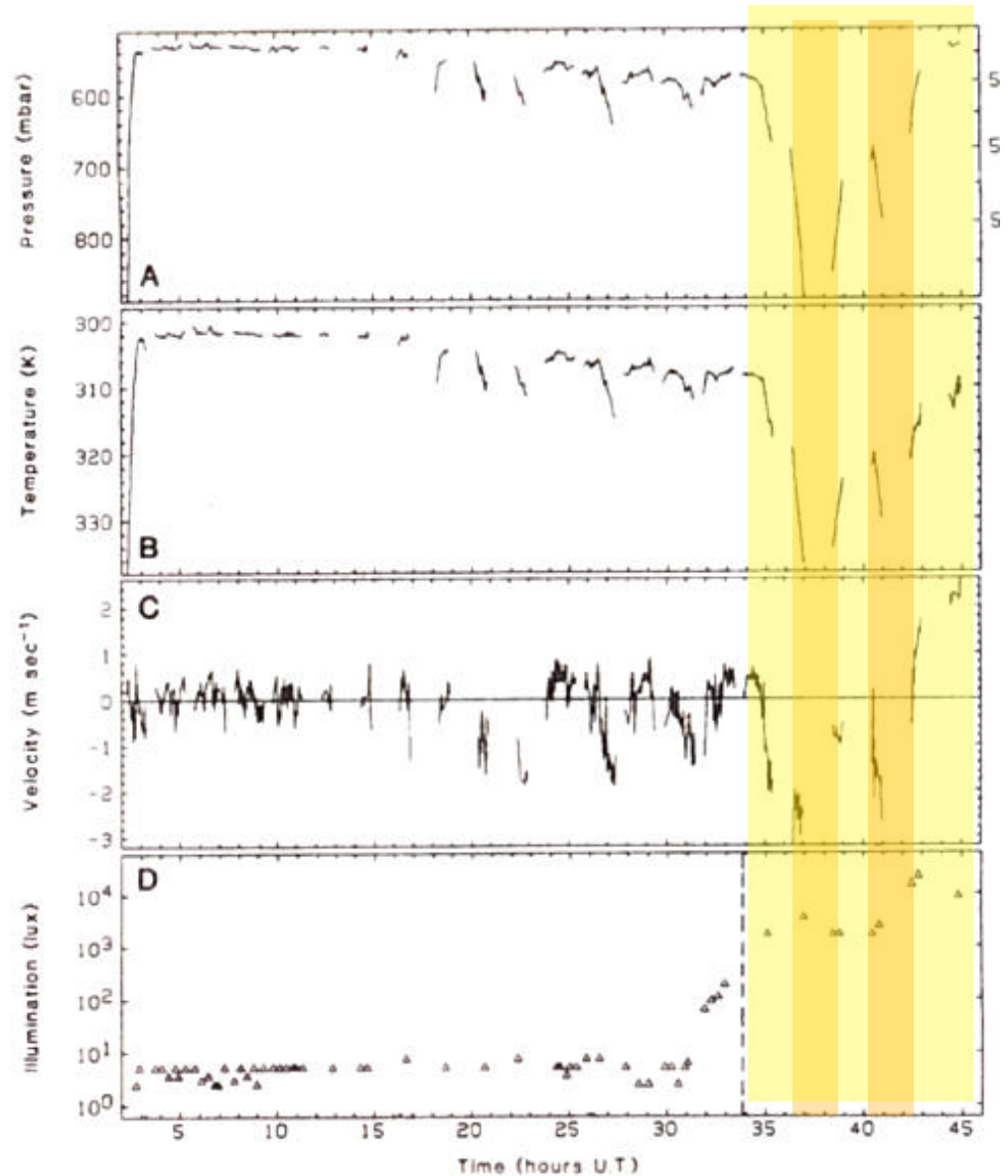
- Pressure (mBar) ↓
- Temperature (K) ↓
- Derived vertical wind velocity (m/s)
- Illumination (lux) ↑



Sagdeev et al. Science (1985)

VEGA 2

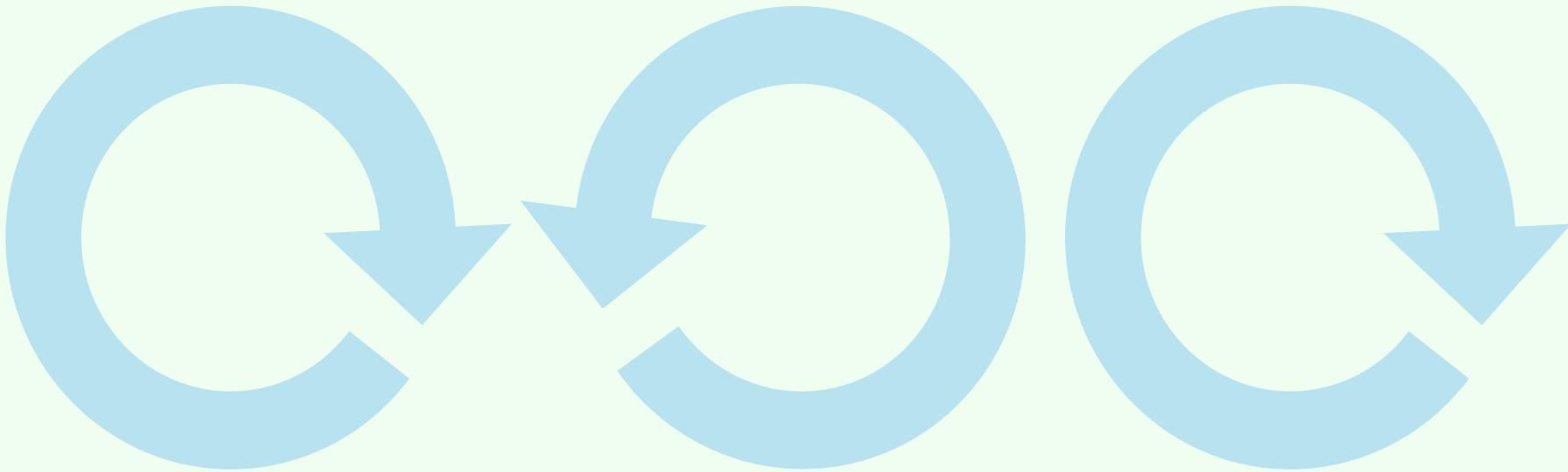
- Pressure (mBar)
- Temperature (K)
- Derived vertical wind velocity (m/s)
- Illumination (lux)



Sagdeev et al. Science (1985)

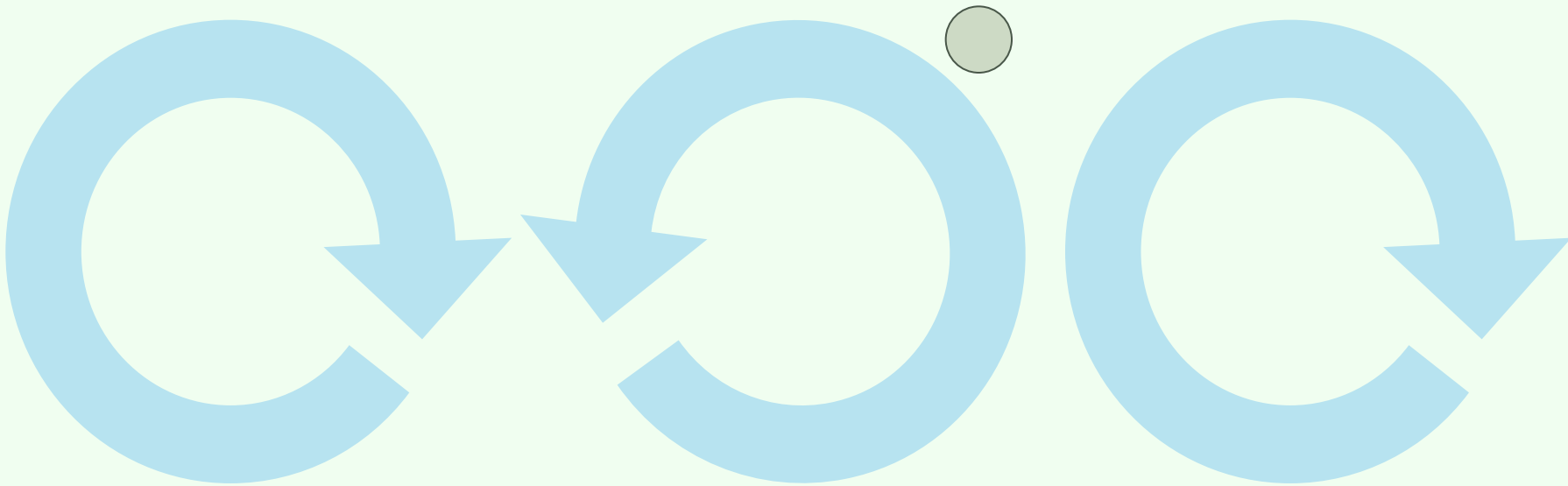
Drift towards downward wind velocity zones

Convection region 48-55 km



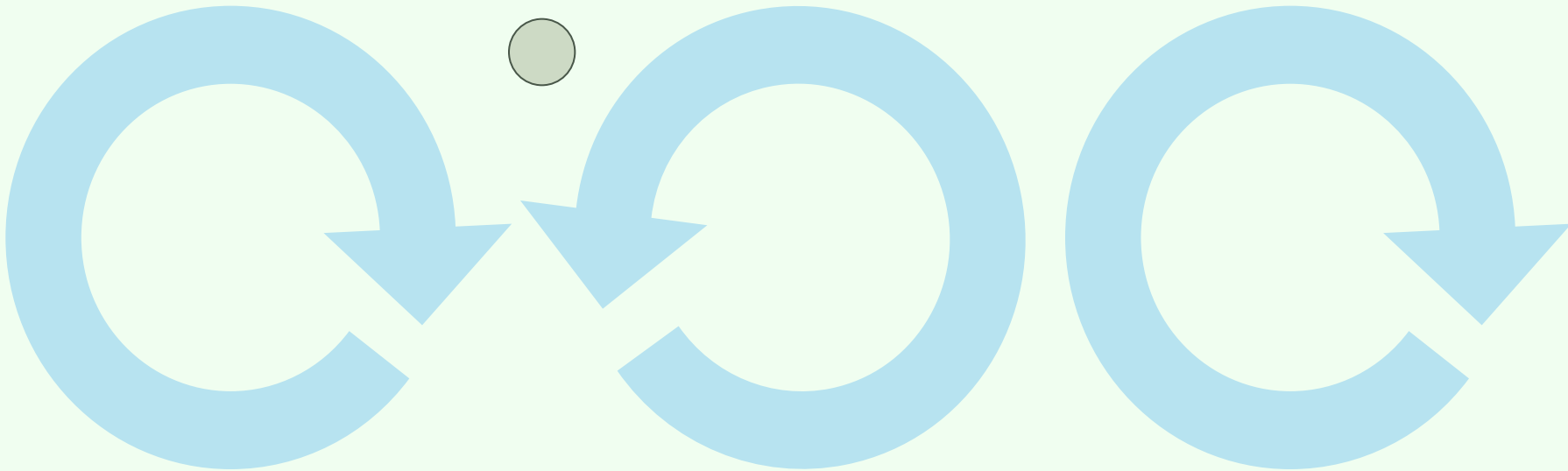
Drift towards downward wind velocity zones

SPB above convection region drifts laterally towards convergent zones



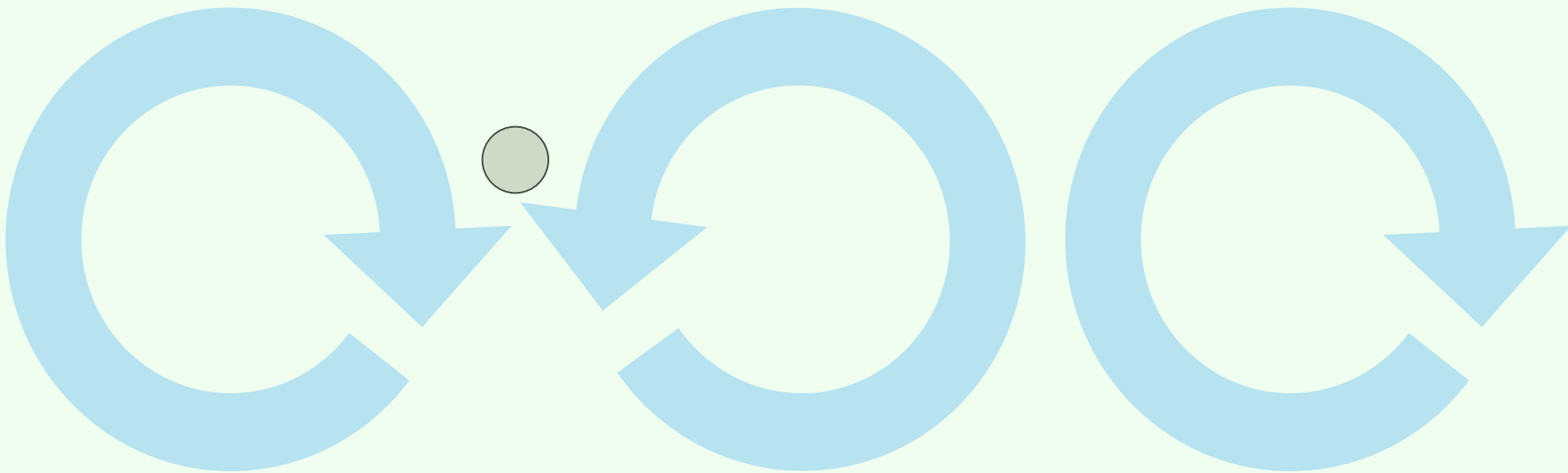
Drift towards downward wind velocity zones

‘Subduction’ of SPB into downward convergence zone



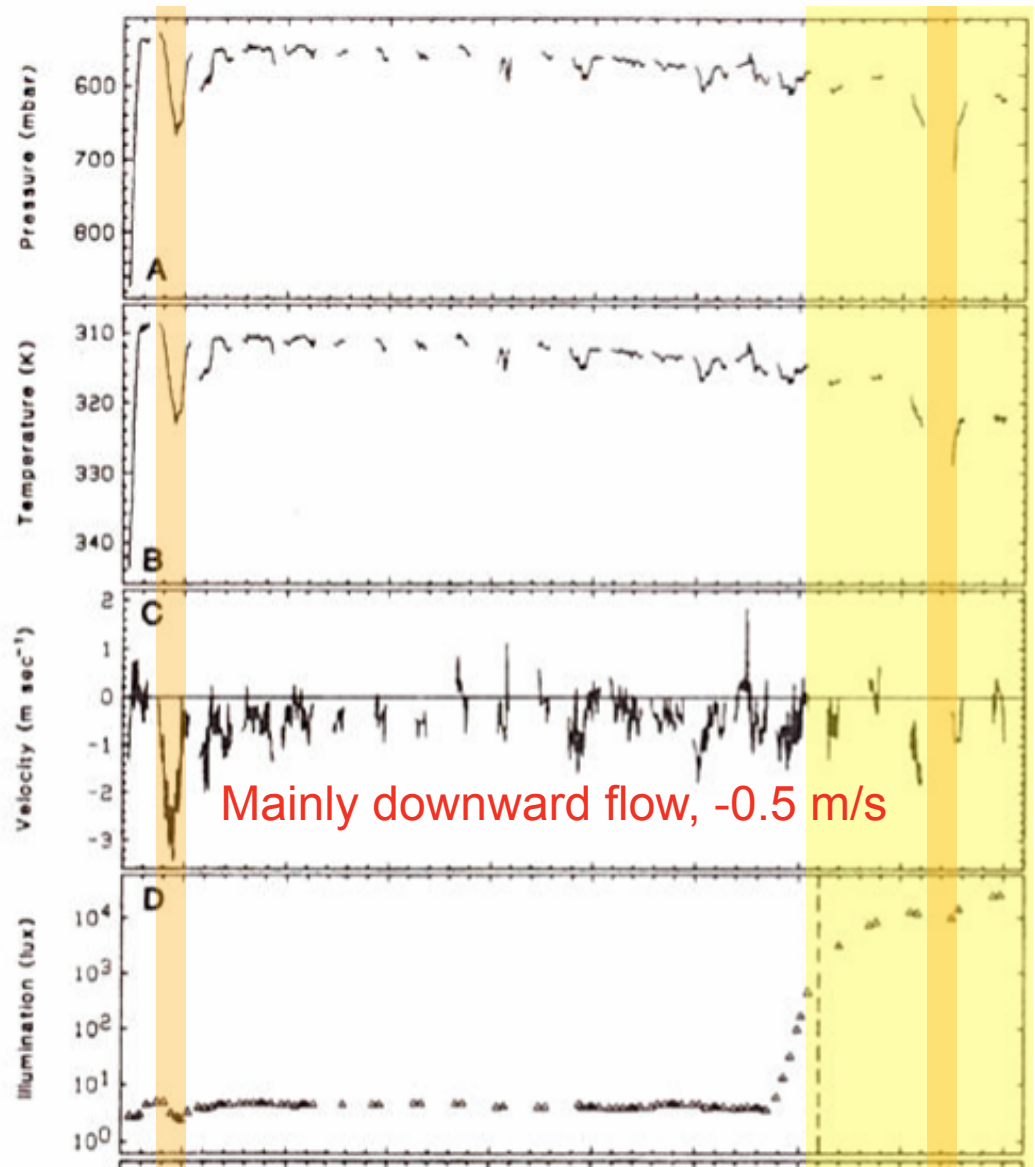
Drift towards downward wind velocity zones

Bobbing in downward winds – dependent on super-pressure stabilisation



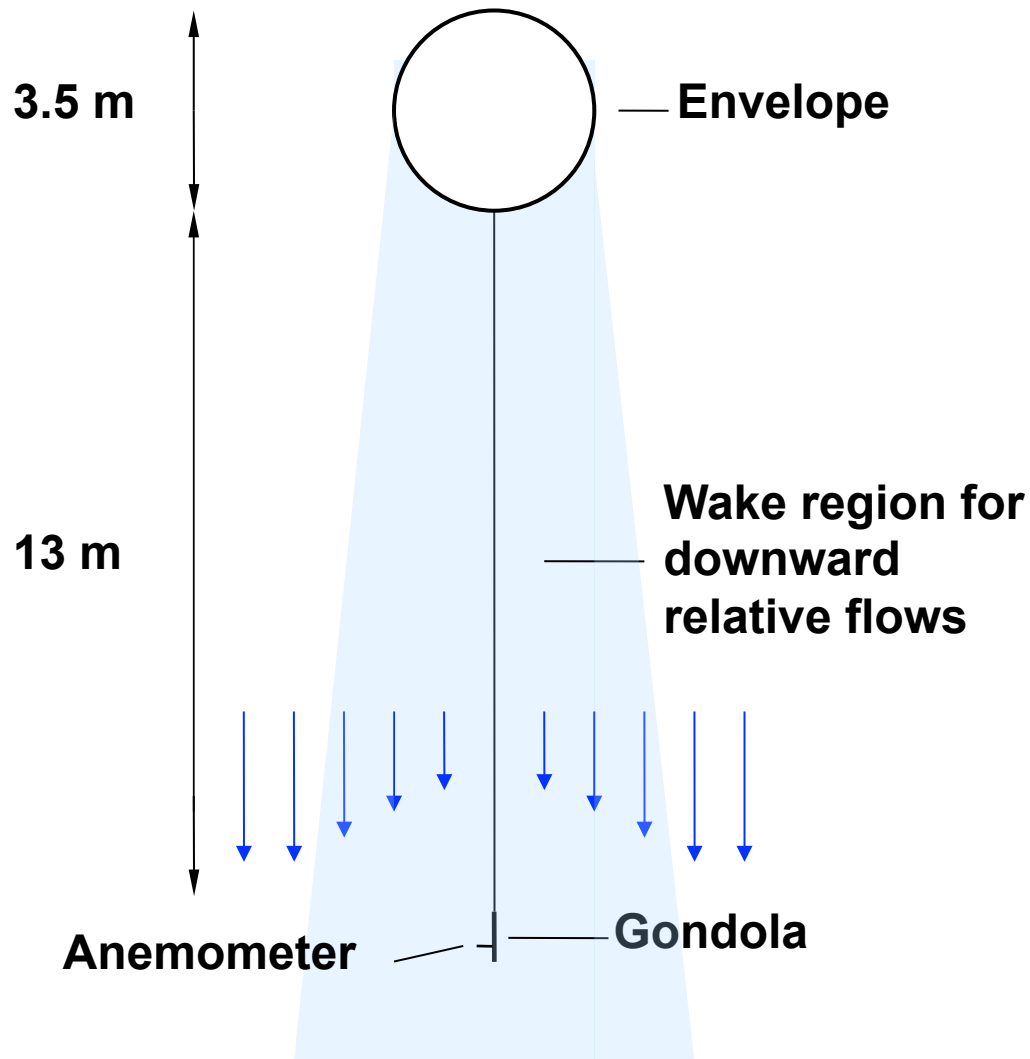
Vega 1

- Pressure (mBar) ↓
- Temperature (K) ↓
- Derived vertical wind velocity (m/s)
- Illumination (lux) ↑



Sagdeev et al. Science (1985)

Vega 1 & 2 wake effects



Wake measurements behind 0.5 m sphere



Test using RMIT Industrial Wind Tunnel Facility

Vega 1

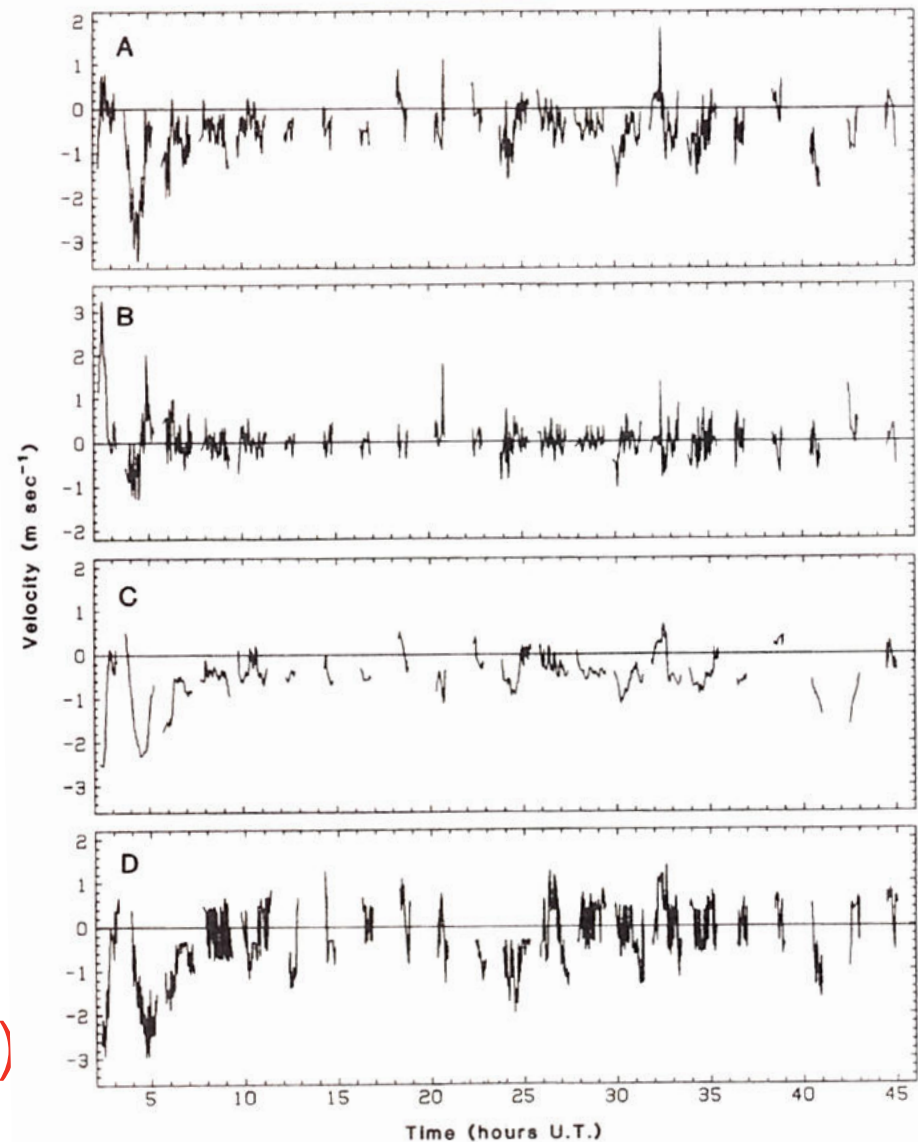
A. Derived vertical wind velocity w

B. Balloon vertical velocity

C. Relative velocity w_{rel}

D. Anemometer velocity

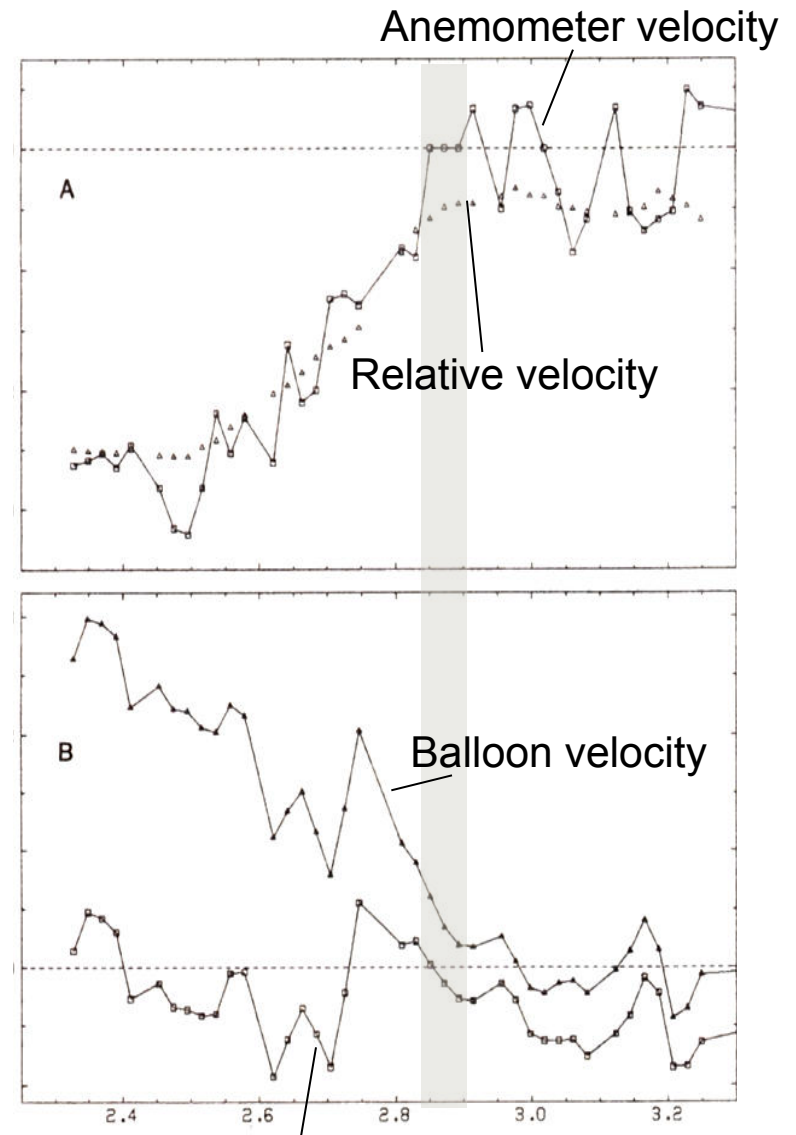
(extra noise caused by wake)



Vega anemometer data

Linkin et al. (1985)
decided to only use
anemometer data to
establish zero relative
flow conditions

And thereby establish the
leakage rate (5%) over 46
hours



Derived vertical wind velocity

Vertical equation of motion:

$$(M + k\rho V) \frac{\partial^2 z}{\partial t^2} = (1 + k) \rho V \frac{\partial w}{\partial t} - F_D - Mg + \rho g V$$

Apparent mass term k not properly known for separated flows

$$F_D = \frac{1}{2} \rho A C_D \left(\frac{\partial z}{\partial t} - w \right) \left| \frac{\partial z}{\partial t} - w \right|$$

Drag coefficient term C_D only known approximately, 20% error?

Derived vertical wind velocity, w

Reduction by Linkin et al. (1985):

$$\frac{1}{2} \rho A C_D w_{rel} |w_{rel}| = \rho g V - Mg$$

$$w_{rel} = \frac{1}{\rho g} \frac{\partial P}{\partial t} - w = \frac{RT}{gP} \frac{\partial P}{\partial t} - w$$

Linear envelope volume relation (e = elasticity parameter):

$$V = V_0 (P_H - P) / (eP_0) + V_0$$

Linkin et al. (1985) “compute” helium pressure and hence envelope volume in order to derive w

Derived vertical wind velocity

Volume of envelope may actually be derived directly,

$$V / V_0 = \{e - p + \sqrt{(e - p)^2 + 4e\theta\sigma}\} / 2e$$

$$p = P/P_0, \quad \frac{W}{W_0} = T_H/T_{H0}, \quad \frac{W}{W_0} = m/m_{H0}$$

But

- 1) elasticity parameter is dependent on modulus of elasticity of TeflonTM (PTFE) envelope (variable in domain of interest), implies that linear volume relation used is doubtful
- 2) Linkin et al. assumed helium temperature is same as ambient (after float height attained and before sunrise)
- 3) Any precipitation (?) on envelope would change mass

VEGA SPB summary

- Vega derived wind velocity may have an error of about ± 0.4 m/s, but raw flight data is needed to verify this claim
- What happened to Vega 1 & 2 after transmission loss?
 - They may have completed multiple circumnavigations
 - Or they may have suffered super-heating at midday and subsequent helium venting and premature irreversible descent

EVE (2010) Proposal

- Float of 240 hours to “guarantee at least one circumnavigation of Venus” at 55 km
- Science goals include cloud chemistry and measurements of noble gas isotopic ratios, as well as meteorology.
 - Scientific payload (15-20 kg)
 - More power (40 W) and capacity (8600 Wh) than VEGA, solar power augmentation during daytime
 - 5 m diameter envelope for 60 kg float mass (3.5 m VEGA)

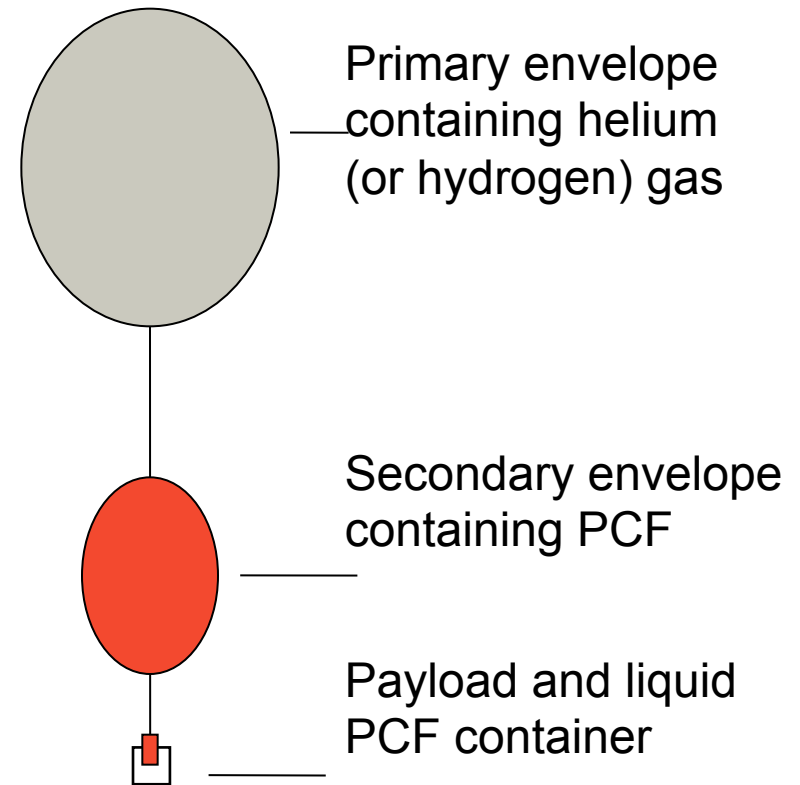
Concerns about EVE (2010)

- ESA concerned that choice of 55 km does not permit sampling of other altitudes, e.g., dense lower cloud with large mode 3 particles (49 km) and unknown UV absorber (70 km)
- Anemometer will be in downward flow (repeating VEGA again)
- Smooth sphere is subject to lateral oscillations (could be mitigated by using a JIMSPHERE)
- Super-heating a midday remains a concern (loss of mission). Vertical stability of SPB is improved by using higher strength envelope with higher e value, but this is weak effect. Terrestrial long endurance SPB experience (e.g. “VORCORE”) has been limited to relatively calm stratospheric flight with low vertical wind velocities (cm/s) but mission loss is typically more than 5%.
- Heavy helium/hydrogen storage tank (75 kg) required

Alternative Platform Options

Free Balloon with Phase Change Fluid (PCF)

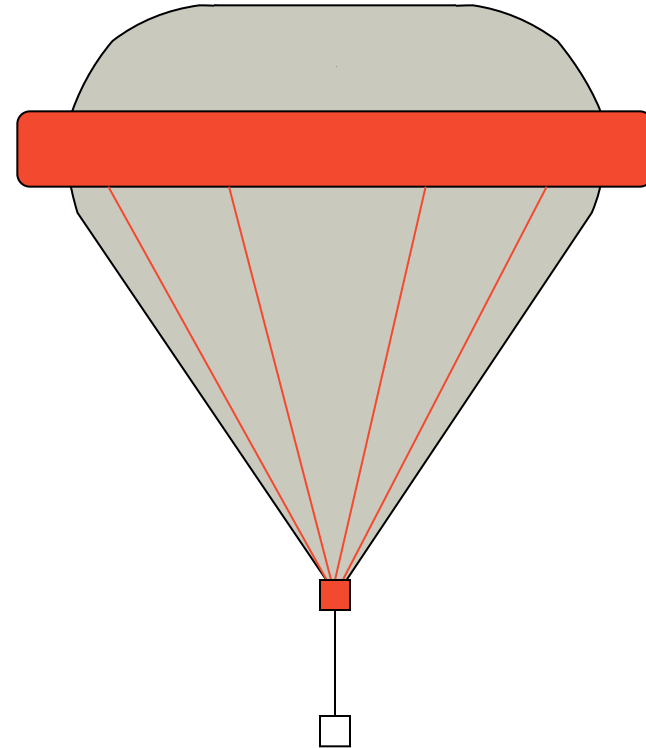
Tandem Configuration Schematic



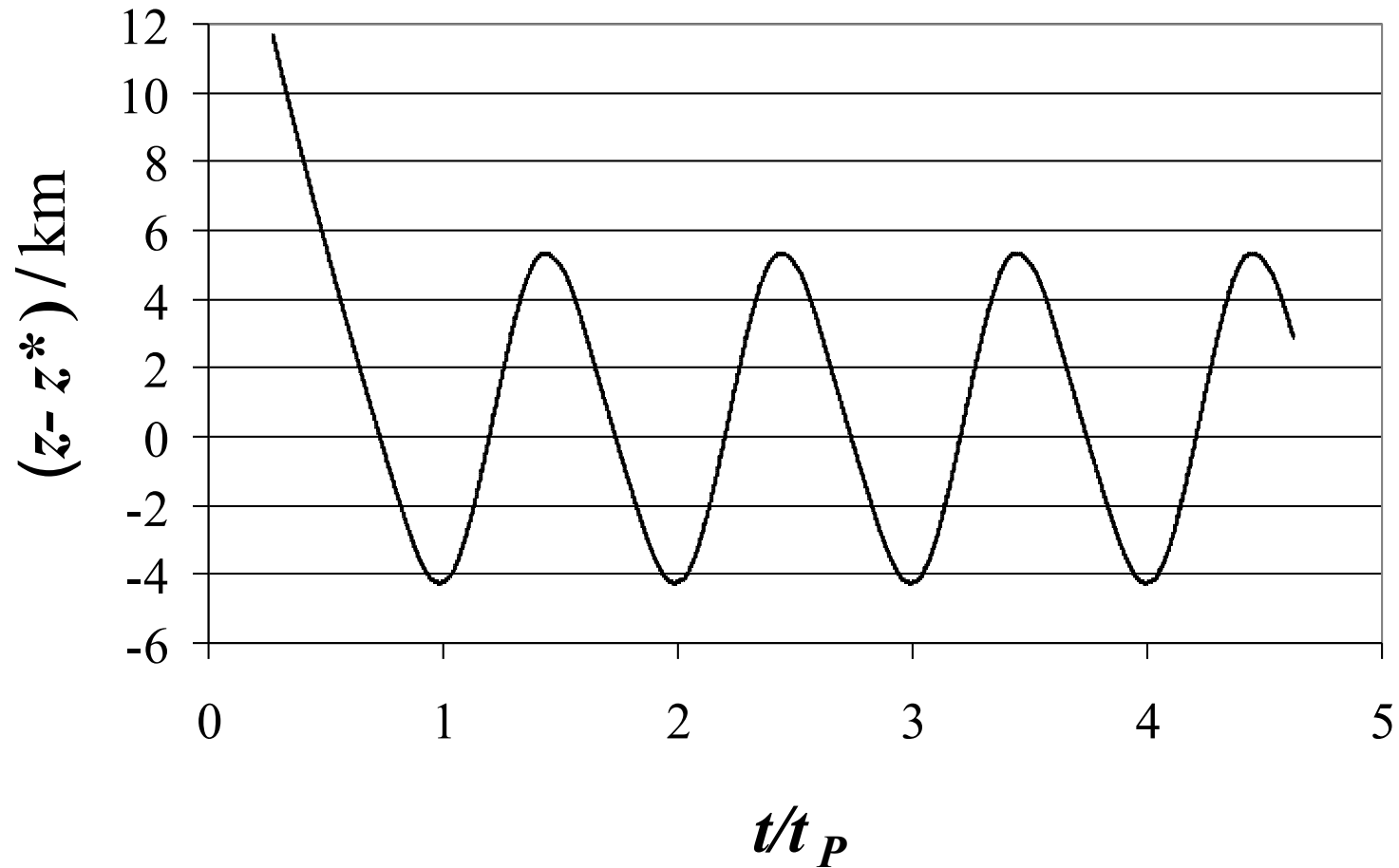
Free Balloon with Phase Change Fluid (PCF)

Toroidal Configuration

Schematic



Vertical Oscillation (H₂O helium tandem)



Phase Change Fluid (PCF) options

Higher MW PCFs increase oscillation altitude, but reduce payload fraction

| PCF | Mol W. / (gram mols) | P * | T* | z* |
|-------------|-------------------------|------|-----|----|
| acetic acid | 60 | 0.71 | 467 | 33 |
| water | 18 | 0.28 | 404 | 42 |
| ethanol | 46 | 0.11 | 355 | 49 |
| methanol | 32 | 0.08 | 332 | 52 |
| acetone | 58 | 0.07 | 316 | 54 |
| pentane | 72 | 0.04 | 284 | 57 |

Oscillating Phase Change Balloons

- Have been demonstrated in Earth troposphere (ALICE)
- Well known thermodynamics govern predicted oscillation
- High risk deployment and initial helium/hydrogen inflation can be tested at similar Earth-Venus conditions
- Secondary envelope offers low altitude safety “buffer” (reducing mission risk)
- Permits multiple traverses of cloud layers
- MIL specification electronics possible down to 43 km (PCF evaporation cools payload).
- Slightly reduced payload ratio

Other Options Requiring Study

Infra-Red Montgolfière

Fixed-Wing Gliders (6 hours)

Parawings (solar power, 10 hours)

Vetrolets (wind shear dependent)

Etc.



Conclusions

VEGA 1 & 2 SPB flights

rank with major aeronautical historical events

but may not have circumnavigated Venus after power loss

For (multiple) circumnavigation of Venus

Phase Change Balloons offer:

- 1) lower risk of premature mission loss
- 2) multiple traverses of cloud layers

The Birth of Venus, William Adolphe Bouguere



End